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PORTABLE ELECTRIC MINE LAMPS

BY

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PORTABLE ELECTRIC MINE LAMPS.

By H. H. Clark.

INTRODUCTION.

The object of this paper is to discuss the use of portable electric mine lamps, to point out certain advantages that such lamps possess, and to suggest some characteristics that they ought to have.

The manufacture and the use of portable electric mine lamps are just beginning in the United States. Several manufacturers are now developing such lamps and mine operators are manifesting an interest in their use. Portable electric lamps have already been introduced in a number of the mines of this country.

The Bureau of Mines is interested in this subject because the engineers of the bureau believe that the safety of mining operations would be increased in a large measure because of the lessened danger of gas explosions and mine fires, by the abandonment of open lights underground and the universal adoption of properly designed portable electric lamps[a] except for testing for gas.

This paper is written with regard to portable electric lamp equipments as now designed and constructed. All statements made refer to such equipments, the maximum potential of which rarely if ever exceeds 6 volts.

ADVANTAGES OF PORTABLE ELECTRIC LAMPS.

There are two general classes of mine lamps, open-flame lamps and safety lamps, with which portable electric lamps must be compared. The comparison with open-flame lamps may be briefly drawn. An electric bulb is obviously safer than an open flame as regards the ignition of either fire damp or combustible material. For use on a cap, an electric lamp is, on the whole, nearly if not quite as convenient as the open-flame lamp.

In comparing electric lamps and safety lamps the locked type of safety lamp must be considered as the only one that, for safety, is on a par with a well-constructed portable electric lamp. Even the locked type of safety lamp has its weak points. The omission or improper adjustment of some part may render the lamp unsafe and this condition may be effectually hidden from the user of the lamp and continue to exist until the lamp is reopened and readjusted. The user has no means of detecting imperfect arrangement of lamp

[a] In gaseous mines electric lamps should not be used exclusively. Properly constructed safety lamps should be available for gas testing.

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parts and must depend for safety upon the one whose duty it is to prepare the lamps for use. Reports indicate that safety lamps are not always properly adjusted in the lamp house and that they sometimes are issued in an unsafe condition. Just how often this occurs can not be determined, because the condition is not always apparent unless it causes disaster.

The filament of a portable electric lamp is normally surrounded by a vacuum which, as long as it exists, absolutely prevents gas from coming in contact with the filament. If the vacuum is destroyed, the fact becomes evident in a few seconds at most, because the filament becomes dim and soon ceases to glow. Thus there is inherent in the construction of the electric lamp an effectual safeguard whose disappearance is announced automatically, unmistakably, and without delay. Moreover, though the destruction of the vacuum may give rise to a condition of potential danger, the air that takes the place of the vacuum removes the condition in a short time by causing the filament to burn in two.

Therefore, it is not only impossible for the user of a portable electric lamp to remain ignorant of its unsafe condition but it is also impossible for the unsafe condition to endure for more than a fraction of a minute.

Although an electric lamp can not be regarded as a safety lamp, if the latter be defined as a lamp that detects the presence of gas without igniting it, still if the presence of gas is known a well-constructed portable electric lamp, even without special safety devices, would seem to be quite as safe as a safety lamp because, while either may possibly ignite gas as the result of an accident, an unbroken safety lamp may cause disaster if its parts are improperly arranged.

If an electric lamp is so designed that its bulb can not be broken before the filament ceases to glow, the danger of gas ignition is so completely eliminated that it is conceivable only as the result of malicious intent combined with the exercise of skill and ingenuity in restraining the action of the safety devices.

As compared with the safety lamp, the electric lamp is the more convenient because it can be worn upon the cap. The direction of its light is then automatically governed by the movements of the wearer's head and both his hands are free. Another desirable feature of the electric lamp is that it gives more light than a safety lamp.

SOURCES OF DANGER IN PORTABLE ELECTRIC LAMPS.

The author's experiments indicate that the glowing filament is the only source of danger in a portable electric-lamp equipment. The only other possible source of danger would be the sparks to be obtained by breaking the circuit of such an equipment.

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GAS IGNITION BY SPARKS.

The results of recent tests made by the bureau show that such sparks are not capable of igniting mine gas. These tests were made in the most explosive mixture of Pittsburgh natural gas [a] and air under the conditions stated below.

Rotating contacts were made to pass under a metal contact brush, thereby opening and closing, at a speed of 1 centimeter a second, a noninductive direct-current circuit. The source of electrical energy was a generator operating in multiple with a storage battery In one set of tests the rotating contacts were made of carbon and the brush of soft iron. In another set of tests the rotating contacts were made of brass and the brush was made of copper. Carbon and iron were selected as the materials most conducive to violent sparking. Brass and copper were selected as the materials between which the sparks would be drawn in practice. It was planned to thus demonstrate the factor of safety of test conditions over ordinary conditions in mines. In all tests with the carbon-iron contacts the brush was caused to press very lightly upon the rotating contacts. Tests were also made with speed of the rotating contact reduced to 1 centimeter in five seconds. The results of the tests are stated below.

With the carbon-iron contacts a circuit carrying 12 amperes at 15 volts was made and broken 5,000 times without causing the gas to ignite. No gas ignition was obtained from 5,000 tests made under similar conditions with the circuit carrying 18 amperes at 10 volts. The size and brilliancy of the sparks obtained were remarkable, in view of the fact that the gas did not ignite. As the test progressed the carbon contacts became roughened by use and arcking began as soon as the carbon touched the brush and continued during the 1.27 seconds required for the carbon to pass the brush. These tests were made not only in motionless gaseous mixtures but also in a stream of the mixture blown by a small fan directly upon the contacts. The velocity of the jet of gas varied from a gentle breath to a current sufficiently violent to blow to one side the arcs and sparks given off by the contacts.

With the brass-copper contacts a circuit carrying 25 amperes at 15 volts was made and broken 5,000 times without causing an ignition of the gas. No gas ignition was obtained from 2,700 tests made under similar conditions when the circuit was carrying 30 amperes at 10 volts. The sparks obtained by use of the brass-copper contacts were noticeably smaller than those obtained with the carbon-iron contacts. No arcking occurred with fresh clean contacts, until the

[a] Natural gas from the Pittsburgh city mains was used in these tests. As determined by G. A. Burrell, chemist, the composition of this gas is approximately 83.1 per cent methane, 16 per cent ethane, 0.9 per cent nitrogen, and a trace of carbon dioxide. The most explosive mixture of Pittsburgh natural gas and air contains 8.6 per cent gas and 91.4 per cent air.

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contacts began to separate. After the contacts had become worn and pitted by service, sparking and even arcking did occur. Reducing the speed of break to 1 centimeter in 5 seconds had the effect of producing an ignition at 15 volts and 25 amperes after 127 fruitless trials. This ignition was due as much to arcking under the brush as to the slow speed of break. The test was repeated with an increased brush tension to prevent arcking under the brush. No ignition was obtained in 270 trials. Brush tension was reduced, and after 124 fruitless trials another ignition occurred. The current was then reduced to 20 amperes and 500 trials were made without producing an ignition.

Inasmuch as the battery of a portable lamp outfit rarely, if ever, represents a potential greater than 6 volts, and inasmuch as the current taken by the lamps of such outfits does not exceed 1 ampere, the bureau's engineers believe that these tests prove quite conclusively that such sparks as can be obtained from a portable lamp outfit will not ignite gas.

GAS IGNITION BY SHORT-CIRCUITING.

Even if a battery were short circuited (a remote possibility with a properly constructed equipment) and then open circuited, the spark would seldom, if ever, be large enough to cause ignition of gas. The following tests were made to prove this: Eight batteries were mounted in the testing gallery and surrounded by the most explosive mixture of gas and air. The terminals of these batteries were connected directly across the contacts used in all previous tests and the movable contact was rotated at a speed of 1 centimeter per second. The table following states the open-circuit voltage of each battery and the current that flowed when the battery was short circuited through an ammeter.

TABLE 1.—*Open-circuit voltage and short-circuit current of batteries tested.*

Battery.	Number of cells.	Open circuit.	Short circuit.
		Volts.	*Amperes.*
a	1	2.5	80
b	1	2.5	56
c	2	2.6	39
d	1	2.5	35
e	2	2.6	23
f	4	6.0	16
g	1	2.2	10
h	2	3.0	10

Not less than 20 sparks were drawn from each of these batteries under the conditions set forth above. No ignition of the gas took place in any test.

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Inasmuch as the batteries probably deteriorated rapidly under such severe usage, the following test was made to demonstrate that the spark given by high currents at low voltages can not ignite gas. A number of storage batteries were put in multiple with a generator and the combination was connected through a noninductive resistance to the copper-brass spark contacts used in the previous tests. The contacts were surrounded by the most explosive mixture of natural gas and air and were caused to open the circuit at the rate of 1 centimeter per second. One thousand trials were made while the circuit was carrying 100 amperes at 4 volts, 1,000 trials were made while the circuit was carrying 80 amperes at 5 volts, and 1,000 trials were made while the circuit was carrying 55 amperes at 6 volts. The gas was not ignited in any test.

These tests seem to prove conclusively that mine gas can not be ignited by sparks from portable electric-lamp equipments if the batteries used with such equipments are made so that their maximum short-circuit current can not exceed the following values: For batteries giving 2.5 volts or less, 100 amperes; for batteries giving more than 2.5 volts but not more than 4 volts, 85 amperes; for batteries giving more than 4 volts but not more than 5 volts, 65 amperes; for batteries giving more than 5 volts but not more than 6 volts, 45 amperes.[a]

GAS IGNITION BY ARCS.

It must be considered, however, that if the breaking of the lamp circuit develops a continuous spark or arc the likelihood of gas ignition is greatly increased. The possibility of drawing and maintaining an arc with a portable electric-lamp equipment used under normal conditions is remote. The following tests were made in the laboratory to determine the values of current and voltage below which arcs sufficient to ignite gas can not exist.

The same contact device was used in this test as in the previous ones. The moving contact was brass and the stationary brush was copper. The contacts were caused to separate very slowly so that an arc would form if it ever could with the voltage and contacts used.

With an open-circuit potential of 10 volts no arcs could be obtained by breaking 38 amperes. With an open-circuit potential of 15 volts no arc lasting for more than 1 second could be obtained with 30 amperes.

CONCLUSIONS AS TO GAS IGNITION BY SPARKS AND ARCS.

The bureau's engineers consider that the foregoing tests prove conclusively that such sparks and arcs as are obtainable from a

[a] These current values are purposely made less than those obtained in the tests in order to introduce a factor of safety.

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portable electric-lamp outfit of not more than 6 volts are not capable of igniting explosive mixtures of mine gas and air if the short-circuit current of the batteries can not exceed the values stated on a previous page of this paper.

GAS IGNITION BY LAMP FILAMENTS.

Still earlier tests (reported in Technical Paper 23[a] and Bulletin 52[b], Bureau of Mines) show that if, in the presence of gas, a lamp bulb is broken without injury to its filament the gas may become ignited. This dangerous condition can not arise (if the bulb is flexibly mounted so that it can not be broken by a jar imparted to the lamp guard) unless the outside guard of the lamp be smashed and the lamp bulb itself be broken by a blow so nicely calculated that after crushing a conical guard of metal and heavy glass it will shatter a small, nearly spherical glass bulb and then stop short of a delicate filament, leaving the latter intact and even untouched. In making tests in the laboratory it is not difficult to adjust conditions so that lamp bulbs may be smashed without injury to their filaments. Under practical conditions of use, however, it would be a noteworthy exception if a blow that broke a properly mounted lamp bulb failed to destroy its filament also.

However, not even that remote contingency need be feared if the mounting of the lamp bulb be so designed that a blow sufficient to break the bulb will short-circuit it or open the electric circuit of the lamp.

PARTS OF A PORTABLE ELECTRIC LAMP.

A portable electric-lamp equipment consists of three principal parts—an incandescent lamp bulb, an electric battery, and the mounting and connections of the bulb and the battery. Of these three parts the lamp bulb is the most completely developed and standardized. By the use of a tungsten filament a battery of a given capacity can produce at least twice as much light as with the carbon filament formerly used. However, there are large differences in the current consumption of lamp bulbs of the same rating, if the bulbs heretofore supplied to the bureau may be regarded as fair samples of what the market affords. Uniformity of current consumption is an essential qualification of portable lamp bulbs because upon this characteristic depends not only the candlepower of the lamp but also its time of burning upon one charge of battery. Therefore, in order for a manufacturer to guarantee the performance of his equipments he must be assured that the lamp bulbs that he uses will have a reasonably uniform current consumption.

The design of the lamp mounting and connections is still in a state of development, and shape, size, materials, and workmanship vary

[a] Ignition of gas by miniature electric lamps with tungsten filaments, by H. H. Clark. 1913. 5 pp.
[b] Ignition of mine gases by the filaments of incandescent lamps, by H. H. Clark and L. C. Ilsley. 1893. 31 pp., 6 pls.

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with different manufacturers. As yet no manufacturer has standardized even his own equipment, and changes in design and construction are constantly being made. In general two types of lamp are being developed—the hand lamp and the cap lamp. In Europe the hand lamp is used exclusively, or almost exclusively, but the sentiment in the United States seems to favor the cap lamp on account of its greater convenience.

At present the battery seems to be the most important part of the portable electric-lamp equipment. If a suitable battery can be devised, the rest of the equipment is already developed to a satisfactory degree, although some day another improvement in lamp filaments may again revolutionize the design of portable lamps.

The ideal battery will combine large capacity, long life of charge, and uniformity of voltage with light weight, simplicity and convenience in handling and charging, and low cost of upkeep. The electrolyte of such a battery will require a minimum of attention to maintain the amount and quality at its normal value. It will not be possible for the electrolyte to spill or to leak from the battery. It will be convenient to determine at any time the state of the battery charge or else that condition will not be a factor in charging—that is, overcharge will not injure the cells. Such a battery will give a high voltage per cell, so that with the fewest cells the lamp filament may be as long as possible, since length of filament, up to a certain length, promotes efficiency.

The combination of all these desirable features in one battery does not seem to have been effected as yet, but development is still going on and numerous improvements may reasonably be expected.

CONSIDERATIONS IN THE DESIGN OF LAMP EQUIPMENT.

In mines where gas is likely to be met the first consideration is safety. In mines where gas is not found the electric lamp can not be regarded as a source of danger under any circumstances.

After safety, the next consideration is the production of a proper amount of light for approximately 10 hours on one charge. The next is reliability of service, which is affected by several things that will be mentioned later. The service given by the lamp should not be interrupted as a result of mechanical or electrical defects or weaknesses. Lightness probably follows reliability of service in importance, but almost, if not quite, as important is durability. If the equipment is strong and is designed and constructed so as to resist and minimize wear, both depreciation and repair charges are thereby reduced and reliability of service increased. Convenience in handling and charging is a characteristic that, if attained, will materially aid the introduction of portable electric lamps for mine use. To be suitable for underground work the lamp outfits should not leak or spill

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electrolyte, and it should not be necessary for the users to exercise any care to prevent such an occurrence.

In batteries that can not be overcharged without injury, the condition of charge is important, and in order to increase reliability of service there should be means for the easy and accurate observation of the state of charge by the caretaker. It is also highly desirable that the maintenance of the electrolyte in its normal amount and condition should be a simple procedure requiring a minimum of attention. Anything that makes for a reduction in the care and attention demanded by the outfit reduces expense and makes for reliability of service.

Finally, it is desirable that a battery should hold its charge during long periods of idleness and that a minimum of attention should be required to keep it in condition during such periods.

INVESTIGATIONS BY THE BUREAU OF MINES.

The Bureau of Mines is at present engaged in an investigation of all the patterns of portable electric mine lamps that, as far as the bureau is aware, are manufactured in the United States. All of the characteristics of each lamp equipment, as well as its safety for use in gaseous mines, are being considered. Any manufacturer of portable electric mine lamps may have his equipment included in this investigation by applying to the director of the bureau for permission to submit equipment for test. Upon receipt of such a request the director will inform the applicant how many outfits and spare parts will be needed and where and to whom the equipment should be shipped.

PUBLICATIONS ON MINE ACCIDENTS AND METHODS OF MINING.

The following Bureau of Mines publications may be obtained free by applying to the Director, Bureau of Mines, Washington, D. C.

BULLETIN 10. The use of permissible explosives, by J. J. Rutledge and Clarence Hall. 1912. 34 pp., 5 pls., 4 figs.

BULLETIN 17. A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall. 61 pp., 10 pls., 12 figs. Reprint of United States Geological Survey Bulletin 423.

BULLETIN 20. The explosibility of coal dust, by G. S. Rice, with chapters by J. C. W. Frazer, Axel Larsen, Frank Haas, and Carl Scholz. 204 pp., 14 pls., 28 figs Reprint of United States Geological Survey Bulletin 425.

BULLETIN 44. First national mine-safety demonstration, Pittsburgh, Pa., October 30 and 31, 1911, by H. M. Wilson and A. H. Fay, with a chapter on the explosion at the experimental mine, by G. S. Rice. 1912. 75 pp., 7 pls., 4 figs.

BULLETIN 46. An investigation of explosion-proof mine motors, by H. H. Clark. 1912. 44 pp., 6 pls., 14 figs.

BULLETIN 48. The selection of explosives used in engineering and mining operations, by Clarence Hall and S. P. Howell. 1912. 50 pp., 3 pls., 7 figs.

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BULLETIN 52. Ignition of mine gases by the filaments of incandescent lamps, by H. H. Clark and L. C. Ilsley. 1912. 31 pp., 6 pls., 2 figs.

BULLETIN 65. Oil and gas wells through workable coal beds; papers and discussions, by G. S. Rice, O. P. Hood, and others. 1913. 101 pp., 1 pl., 10 figs.

TECHNICAL PAPER 4. The electrical section of the Bureau of Mines, its purpose and equipment, by H. H. Clark. 1911. 12 pp.

TECHNICAL PAPER 11. The use of mice and birds for detecting carbon monoxide after mine fires and explosions, by G. A. Burrell. 1912. 15 pp.

TECHNICAL PAPER 13. Gas analysis as an aid in fighting mine fires, by G. A. Burrell and F. M. Seibert. 1912. 16 pp., 1 fig.

TECHNICAL PAPER 17. The effect of stemming on the efficiency of explosives, by W. O. Snelling and Clarence Hall. 1912. 20 pp., 11 figs.

TECHNICAL PAPER 19. The factor of safety in mine electrical installations, by H. H. Clark. 1912. 14 pp.

TECHNICAL PAPER 21. The prevention of mine explosions; report and recommendations, by Victor Watteyne, Carl Meissner, and Arthur Desborough. 12 pp. Reprint of United States Geological Survey Bulletin 369.

TECHNICAL PAPER 23. Ignition of mine gas by miniature electric lamps, by H. H. Clark. 1912. 5 pp.

TECHNICAL PAPER 24. Mine fires, a preliminary study, by G. S. Rice. 1912. 51 pp., 1 fig.

TECHNICAL PAPER 27. Monthly statement of coal-mine accidents in the United States, January to August, 1912, including statistics for 1910 and 1911, compiled by F. W. Horton. 1912. 24 pp.

TECHNICAL PAPER 28. Ignition of mine gas by standard incandescent lamps, by H. H. Clark. 1912. 6 pp.

TECHNICAL PAPER 32. The cementing process of excluding water from oil wells, as practiced in California, by Ralph Arnold and V. R. Garfias. 1913. 12 pp., 1 fig.

MINERS' CIRCULAR 3. Coal-dust explosions, by G. S. Rice. 1911. 22 pp.

MINERS' CIRCULAR 4. The use and care of mine-rescue breathing apparatus, by J. W. Paul. 1911. 24 pp., 5 figs.

MINERS' CIRCULAR 5. Electrical accidents in mines; their causes and prevention, by H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 1911. 10 pp., 3 pls.

MINERS' CIRCULAR 6. Permissible explosives tested prior to January 1, 1912, and precautions to be taken in their use, by Clarence Hall. 1912. 20 pp.

MINERS' CIRCULAR 9. Accidents from falls of roof and coal, by G. S. Rice. 1912. 16 pp.

MINERS' CIRCULAR 10. Mine fires and how to fight them, by J. W. Paul. 1912. 14 pp.

MINERS' CIRCULAR 11. Accidents from mine cars and locomotives, by L. M. Jones. 1912. 16 pp.

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